Naive Learning in Social Networks and the Wisdom of Crowds

Benjamin Golub Graduate School of Business Matthew O. Jackson Department of Economics

ヘロン 人間 とくほ とくほ とう

3

Stanford University

July 13, 2008

Motivation

• When do large societies aggregate information well and when is a lot of information "wasted"?

ヘロン 人間 とくほ とくほ とう

E DQC

Motivation

- When do large societies aggregate information well and when is a lot of information "wasted"?
- We build on a model where:

ヘロト 人間 とくほ とくほ とう

E DQC

Motivation

- When do large societies aggregate information well and when is a lot of information "wasted"?
- We build on a model where:
 - Agents explicitly discuss beliefs (not 0/1 choices).

ヘロト 人間 とくほ とくほ とう

= 990

Motivation

- When do large societies aggregate information well and when is a lot of information "wasted"?
- We build on a model where:
 - Agents explicitly discuss beliefs (not 0/1 choices).
 - Relationships/trust in the social network can vary in strength (not 0/1 links).

ヘロン 人間 とくほ とくほ とう

3

Motivation

- When do large societies aggregate information well and when is a lot of information "wasted"?
- We build on a model where:
 - Agents explicitly discuss beliefs (not 0/1 choices).
 - Relationships/trust in the social network can vary in strength (not 0/1 links).
- Useful features of model:

・ 同 ト ・ ヨ ト ・ ヨ ト …

1

Motivation

- When do large societies aggregate information well and when is a lot of information "wasted"?
- We build on a model where:
 - Agents explicitly discuss beliefs (not 0/1 choices).
 - Relationships/trust in the social network can vary in strength (not 0/1 links).
- Useful features of model:
 - Tractability; easy and explicit measures of dynamics and influence.

ヘロト ヘアト ヘビト ヘビト

1

Motivation

- When do large societies aggregate information well and when is a lot of information "wasted"?
- We build on a model where:
 - Agents explicitly discuss beliefs (not 0/1 choices).
 - Relationships/trust in the social network can vary in strength (not 0/1 links).
- Useful features of model:
 - Tractability; easy and explicit measures of dynamics and influence.

ヘロン 不通 とくほ とくほ とう

• Can study trade-offs involving widely observed agents.

Motivation

- When do large societies aggregate information well and when is a lot of information "wasted"?
- We build on a model where:
 - Agents explicitly discuss beliefs (not 0/1 choices).
 - Relationships/trust in the social network can vary in strength (not 0/1 links).
- Useful features of model:
 - Tractability; easy and explicit measures of dynamics and influence.
 - Can study trade-offs involving widely observed agents.
 - Many interesting networks have poor learning; many also have good learning.

ヘロン ヘアン ヘビン ヘビン

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

◆□ ▶ ◆□ ▶ ◆ □ ▶ ◆ □ ▶ ● □ ● ● ● ●

Agents and Beliefs

• There are *n* agents, indexed by a set $A = \{1, 2, ..., n\}$.

Introduction Belia Model and Definitions Com Results Wise Conclusion Pror

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

◆□ ▶ ◆□ ▶ ◆ □ ▶ ◆ □ ▶ ● □ ● ● ● ●

- There are *n* agents, indexed by a set $A = \{1, 2, ..., n\}$.
- Everybody is trying to estimate an unknown parameter $\theta \in \mathbb{R}$.

Introduction Beliefs Model and Definitions Conver Results Wisdon Conclusion Promin

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

・ロト ・ 同ト ・ ヨト ・ ヨト … ヨ

- There are *n* agents, indexed by a set $A = \{1, 2, ..., n\}$.
- Everybody is trying to estimate an unknown parameter $\theta \in \mathbb{R}$.
- Time is discrete:
 - $t = 0, 1, 2, \dots$ Think of these as days.

Introduction Beliefs a Model and Definitions Converg Results Wisdom Conclusion Promine

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほ とくほ とう

э.

- There are *n* agents, indexed by a set $A = \{1, 2, ..., n\}$.
- Everybody is trying to estimate an unknown parameter $\theta \in \mathbb{R}$.
- Time is discrete:
 - $t = 0, 1, 2, \dots$ Think of these as days.
- The estimate or *belief* of agent *i* at time *t* is $b_i(t)$.

Introduction Beliefs Model and Definitions Conver Results Wisdon Conclusion Promin

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほ とくほ とう

э.

- There are *n* agents, indexed by a set $A = \{1, 2, ..., n\}$.
- Everybody is trying to estimate an unknown parameter $\theta \in \mathbb{R}$.
- Time is discrete:
 - $t = 0, 1, 2, \dots$ Think of these as days.
- The estimate or *belief* of agent *i* at time *t* is $b_i(t)$.
- The vector of all beliefs is $\mathbf{b}(t) \in \mathbb{R}^n$.

Introduction Beliefs Model and Definitions Converg Results Wisdom Conclusion Promine

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

・ロト ・ 同ト ・ ヨト ・ ヨト … ヨ

Agents and Beliefs

- There are *n* agents, indexed by a set $A = \{1, 2, ..., n\}$.
- Everybody is trying to estimate an unknown parameter $\theta \in \mathbb{R}$.
- Time is discrete:

 $t = 0, 1, 2, \dots$ Think of these as days.

- The estimate or *belief* of agent *i* at time *t* is $b_i(t)$.
- The vector of all beliefs is $\mathbf{b}(t) \in \mathbb{R}^n$.
- The initial beliefs $b_i(0)$ are independent random draws with mean θ and all lie in the same compact set [-K, K].

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

くロト (過) (目) (日)

э

Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

くロト (過) (目) (日)

э

Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

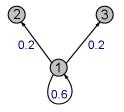
$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$



イロト イポト イヨト イヨト

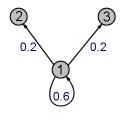
э

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$



 $b_1(t+1) = +$

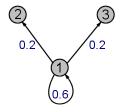
э

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$



$$b_1(t+1) = .6b_1(t) + +$$

< < >> < </>

э

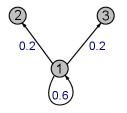
★ 문 ► ★ 문 ►

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$



$$b_1(t+1) = .6b_1(t) + .2b_2(t)$$

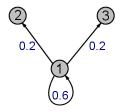
イロト イポト イヨト イヨト

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

$$b_i(t+1) = \sum_{i \in A} T_{ij}b_j(t)$$



$$b_1(t+1) = .6b_1(t) + .2b_2(t)$$

+ .2b_3(t)

イロト イポト イヨト イヨト

э

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

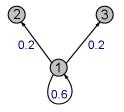
Updating of Beliefs (DeGroot 1974)

The belief of agent *i* at time t + 1 is a weighted average of the beliefs of some agents (possibly including himself!) at time *t*.

$$b_i(t+1) = \sum_{j \in A} T_{ij} b_j(t)$$

where

$$\sum_{j\in A} T_{ij} = 1.$$



$$b_1(t+1) = .6b_1(t) + .2b_2(t) + .2b_3(t)$$

イロト イポト イヨト イヨト

э

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

ヘロト 人間 とくほとくほとう

Updating of Beliefs: Matrix Form

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

Updating of Beliefs: Matrix Form

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$

Let **T** be a matrix whose (i, j) entry is T_{ij} .

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

Updating of Beliefs: Matrix Form

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$

Let **T** be a matrix whose (i, j) entry is T_{ij} .

$$\mathbf{b}(t+1) = \mathbf{T}\mathbf{b}(t)$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

Updating of Beliefs: Matrix Form

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$

Let **T** be a matrix whose (i, j) entry is T_{ij} .

$$\mathbf{b}(t+1) = \mathbf{T}\mathbf{b}(t)$$

$$\Rightarrow$$
 b(t) = **T**^t**b**(0).

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

◆□ ▶ ◆□ ▶ ◆ □ ▶ ◆ □ ▶ ◆ □ ● ● ○ ○ ○

Updating of Beliefs: Matrix Form

$$b_i(t+1) = \sum_{j \in A} T_{ij}b_j(t)$$

Let **T** be a matrix whose (i, j) entry is T_{ij} .

$$\mathbf{b}(t+1) = \mathbf{T}\mathbf{b}(t)$$

$$\Rightarrow$$
 b(t) = **T**^t**b**(0).

Also, $\sum_{j \in A} T_{ij} = 1 \implies$ each row of **T** sums to 1.

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

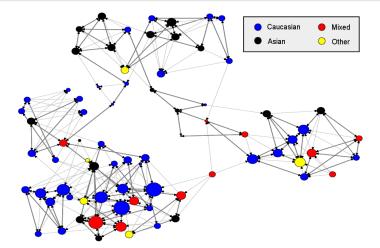
くロト (過) (目) (日)

The Social Network

The matrix **T** naturally corresponds to a social network. The entry T_{ij} describes the "trust" or "weight" that agent *i* places on the beliefs of agent *j* in forming his next-period beliefs.

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Friendships at Westridge School



Jacob K. Goeree, Maggie McConnell, Tiffany Mitchell, Tracey Tromp, and Leeat Yariv, A simple 1/d law of giving, mimeo., Caltech, 2006.

Introduction Beliefs and Networks Model and Definitions Convergence Results Wisdom Conclusion Prominent Groups and Famil



Under some fairly mild conditions, the belief of each individual *i* eventually settles down to some limit

 $b_i(\infty) = \lim_{t\to\infty} b_i(t).$

Benjamin Golub and Matthew O. Jackson Naive Learning in Social Networks

◆□▶ ◆□▶ ★ □▶ ★ □▶ → □ → の Q ()

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

T⁽¹⁾,

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

$$\mathbf{T}^{(1)}, \mathbf{T}^{(2)},$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

$$\mathbf{T}^{(1)}, \mathbf{T}^{(2)}, \mathbf{T}^{(3)},$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

◆□ ▶ ◆□ ▶ ◆ □ ▶ ◆ □ ▶ ● □ ● ● ● ●

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

 $\mathbf{T}^{(1)}, \mathbf{T}^{(2)}, \mathbf{T}^{(3)}, \ldots,$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

$$\mathbf{T}^{(1)}, \mathbf{T}^{(2)}, \mathbf{T}^{(3)}, \ldots, \mathbf{T}^{(n)},$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

$$\mathbf{T}^{(1)}, \mathbf{T}^{(2)}, \mathbf{T}^{(3)}, \dots, \mathbf{T}^{(n)}, \dots$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

・ロト ・ 理 ト ・ ヨ ト ・

1

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

$$\mathbf{T}^{(1)}, \mathbf{T}^{(2)}, \mathbf{T}^{(3)}, \dots, \mathbf{T}^{(n)}, \dots$$

 Each society *n* has an associated vector of beliefs evolving over time: **b**⁽ⁿ⁾(t).

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

・ロト ・ 同 ト ・ ヨ ト ・ ヨ ト

The Asymptotic Setting

• Now let us consider a sequence of societies, with agents A_n . We assume $|A_n| = n$.

$$\mathbf{T}^{(1)}, \mathbf{T}^{(2)}, \mathbf{T}^{(3)}, \dots, \mathbf{T}^{(n)}, \dots$$

- Each society *n* has an associated vector of beliefs evolving over time: **b**⁽ⁿ⁾(t).
- Assume beliefs in every society converge; let the vector of limiting beliefs in society *n* be **b**⁽ⁿ⁾(∞).

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

E DQC

Definition of Wisdom

Wisdom means that, as society grows large, limiting beliefs converge to the truth.

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト イポト イヨト イヨト

= 990

Definition of Wisdom

Wisdom means that, as society grows large, limiting beliefs converge to the truth.

Definition

The sequence $(\mathbf{T}^{(n)})$ is *wise* if

$$\lim_{n\to\infty}\max_{i\in A_n}|b_i^{(n)}(\infty)-\theta|=0.$$

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

3

Prominent Groups: Preliminaries

• Now return for a moment to the fixed *n* setting.

Introduction Be Model and Definitions Co Results Wi Conclusion Pro

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

ヘロト ヘアト ヘビト ヘビト

3

Prominent Groups: Preliminaries

- Now return for a moment to the fixed *n* setting.
- A group B is merely a subset of the set of agents A.

Introduction Beliefs a Model and Definitions Converg Results Wisdom Conclusion Promine

Beliets and Networks Convergence Wisdom Prominent Groups and Families

ヘロン 人間 とくほ とくほ とう

3

Prominent Groups: Preliminaries

- Now return for a moment to the fixed *n* setting.
- A group B is merely a subset of the set of agents A.
- Denote by $T_{ij}(p)$ the (i, j) entry of \mathbf{T}^{p} .

Prominent Groups: Preliminaries

- Now return for a moment to the fixed *n* setting.
- A group B is merely a subset of the set of agents A.
- Denote by $T_{ij}(p)$ the (i, j) entry of **T**^{*p*}.

Write

$$T_{i,B}(p) = \sum_{j\in B} T_{ij}(p).$$

イロト 不得 とくほ とくほ とう

3

Prominent Groups

• A group *B* is prominent in *p* steps relative to **T** if everyone outside *B* is influenced to some extent by *B* in *p* steps.



Prominent Groups

- A group *B* is prominent in *p* steps relative to **T** if everyone outside *B* is influenced to some extent by *B* in *p* steps.
- The minimal amount of such influence is called the *p*-step prominence of *B*.

Definition

Prominent Groups

- A group *B* is prominent in *p* steps relative to **T** if everyone outside *B* is influenced to some extent by *B* in *p* steps.
- The minimal amount of such influence is called the *p*-step prominence of *B*.

Definition

The group *B* is *prominent in p steps* relative to **T** if for each $i \notin B$,

Prominent Groups

- A group *B* is prominent in *p* steps relative to **T** if everyone outside *B* is influenced to some extent by *B* in *p* steps.
- The minimal amount of such influence is called the *p*-step prominence of *B*.

Definition

The group *B* is *prominent in p steps* relative to **T** if for each $i \notin B$, we have $T_{i,B}(p) > 0$.

Prominent Groups

- A group *B* is prominent in *p* steps relative to **T** if everyone outside *B* is influenced to some extent by *B* in *p* steps.
- The minimal amount of such influence is called the *p*-step prominence of *B*.

Definition

The group *B* is *prominent in p steps* relative to **T** if for each $i \notin B$, we have $T_{i,B}(p) > 0$.

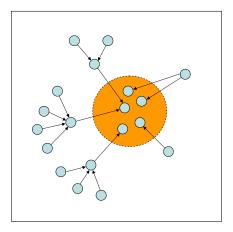
Call $\pi_B(\mathbf{T}; p) = \min_{i \notin B} T_{i,B}(p)$ the *p*-step prominence of *B* relative to **T**.

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト 不得 とくほと くほとう

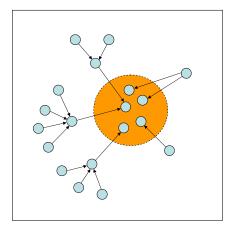
æ

Example of a Prominent Group



Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Example of a Prominent Group



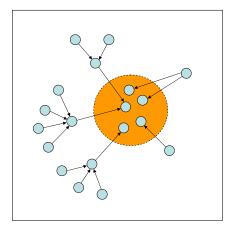
The group in the dashed circle is prominent in 2 steps.

イロト イポト イヨト イヨト

э

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

Example of a Prominent Group



The group in the dashed circle is prominent in 2 steps.

Note that the rest of **T** can be completed arbitrarily.

.⊒...>

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

◆□ ▶ ◆□ ▶ ◆ □ ▶ ◆ □ ▶ ● □ ● ● ● ●

Prominent Families: Intuitive Idea

• Now return to the asymptotic setting. A *family* is just a sequence of groups (*B_n*).

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

ヘロト 人間 とくほ とくほ とう

э.

Prominent Families: Intuitive Idea

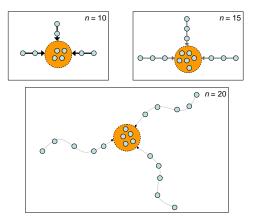
- Now return to the asymptotic setting. A *family* is just a sequence of groups (*B_n*).
- Intuitively: (*B_n*) is uniformly prominent with respect to (**T**⁽ⁿ⁾) means:
 - Each B_n is a prominent group with respect to $\mathbf{T}^{(n)}$.
 - The prominence does not decay to 0.

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

(* E) * E)

э

Prominent Families: What We Are Ruling Out



Beliefs and Networks Convergence Wisdom Prominent Groups and Families

◆□ ▶ ◆□ ▶ ◆ □ ▶ ◆ □ ▶ ● □ ● ● ● ●

Prominent Families: Formal Definition

Definition

The family (B_n) is uniformly prominent relative to $(\mathbf{T}^{(n)})$

Benjamin Golub and Matthew O. Jackson Naive Learning in Social Networks

Beliefs and Networks Convergence Wisdom Prominent Groups and Families

イロト イポト イヨト イヨト

э

Prominent Families: Formal Definition

Definition

The family (B_n) is *uniformly prominent* relative to $(\mathbf{T}^{(n)})$ if there exists a constant $\mu > 0$ so that for each *n*, there is a *p* so that $\pi_{B_n}(\mathbf{T}; p) \ge \mu$.

Small Prominent Families Prevent Wisdom Intuition A Positive Result

・ロト ・ 同ト ・ ヨト ・ ヨト … ヨ

Small Prominent Families Prevent Wisdom

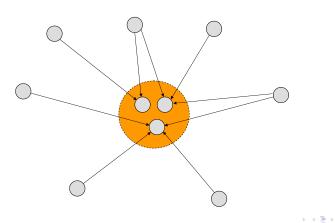
Proposition

If there is a finite, uniformly prominent family with respect to $(\mathbf{T}^{(n)})$, then the sequence is not wise.

Introduction Model and Definitions Results

Small Prominent Families Prevent Wisdom Intuition A Positive Result

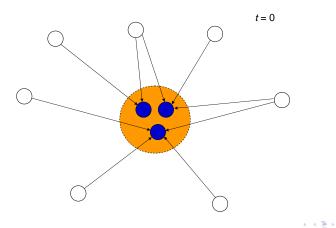
Intuition



Introduction Model and Definitions Results

Small Prominent Families Prevent Wisdom Intuition A Positive Result

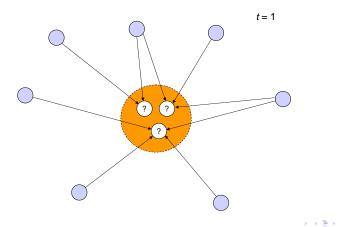
Intuition



Introduction Model and Definitions Results

Small Prominent Families Prevent Wisdom Intuition A Positive Result

Intuition



Small Prominent Families Prevent Wisdom Intuition A Positive Result

ヘロン 人間 とくほ とくほ とう

3

A Positive Result

• A network satisfies *balance* if for every finite family, the ratio of trust coming in to trust coming out is bounded.

Small Prominent Families Prevent Wisdom Intuition A Positive Result

ヘロン 人間 とくほ とくほ とう

3

- A network satisfies *balance* if for every finite family, the ratio of trust coming in to trust coming out is bounded.
- A network satisfies minimal out-dispersion if,

Small Prominent Families Prevent Wisdom Intuition A Positive Result

ヘロン 人間 とくほ とくほ とう

3

- A network satisfies *balance* if for every finite family, the ratio of trust coming in to trust coming out is bounded.
- A network satisfies *minimal out-dispersion* if, for every finite family (*B_n*)

Small Prominent Families Prevent Wisdom Intuition A Positive Result

ヘロン 人間 とくほ とくほ とう

э.

- A network satisfies *balance* if for every finite family, the ratio of trust coming in to trust coming out is bounded.
- A network satisfies *minimal out-dispersion* if, for every finite family (B_n) and every family (C_n) with $|C_n|/n \rightarrow 1$

Small Prominent Families Prevent Wisdom Intuition A Positive Result

・ロト ・ 同ト ・ ヨト ・ ヨト … ヨ

- A network satisfies *balance* if for every finite family, the ratio of trust coming in to trust coming out is bounded.
- A network satisfies *minimal out-dispersion* if, for every finite family (B_n) and every family (C_n) with $|C_n|/n \rightarrow 1$ we have $T_{B_n,C_n} > r > 0$.

Small Prominent Families Prevent Wisdom Intuition A Positive Result

イロト 不得 とくほ とくほ とう

э

A Positive Result

- A network satisfies *balance* if for every finite family, the ratio of trust coming in to trust coming out is bounded.
- A network satisfies *minimal out-dispersion* if, for every finite family (B_n) and every family (C_n) with $|C_n|/n \rightarrow 1$ we have $T_{B_n,C_n} > r > 0$.

Theorem

If $(\mathbf{T}^{(n)})$ satisfies balance and minimum out-dispersion, then it is wise.

Main Implications Further Work

Main Conclusions

- Small prominent groups (media, pundits) are bad for information aggregation when agents are naive.
- Balance and dispersion conditions can guarantee wisdom.

ヘロト ヘアト ヘビト ヘビト

3

Main Implications Further Work

Further Work

Can special kinds of prominent groups ever be good for learning?

イロト 不得 とくほと くほとう

æ –

Main Implications Further Work

Further Work

- Can special kinds of prominent groups ever be good for learning?
- How many "good pollsters" do we need to add to ensure efficient learning, even if the initial structure is very bad?

ヘロト ヘアト ヘビト ヘビト

э

Main Implications Further Work

Further Work

- Can special kinds of prominent groups ever be good for learning?
- How many "good pollsters" do we need to add to ensure efficient learning, even if the initial structure is very bad?
- Interpolate between purely behavioral and purely rational learning.

ヘロト ヘアト ヘビト ヘビト

1

Main Implications Further Work

Further Work

- Can special kinds of prominent groups ever be good for learning?
- How many "good pollsters" do we need to add to ensure efficient learning, even if the initial structure is very bad?
- Interpolate between purely behavioral and purely rational learning.
- Nonhomogeneous updating (updating matrix changes).

ヘロト ヘアト ヘビト ヘビト

1